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Hioki

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(54) **SPARK PLUG**

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H01T 13/32 (2006.01)

(52) **U.S. Cl.**
CPC ***H01T 13/32*** (2013.01)

(58) **Field of Classification Search**
CPC H01T 13/32
See application file for complete search history.

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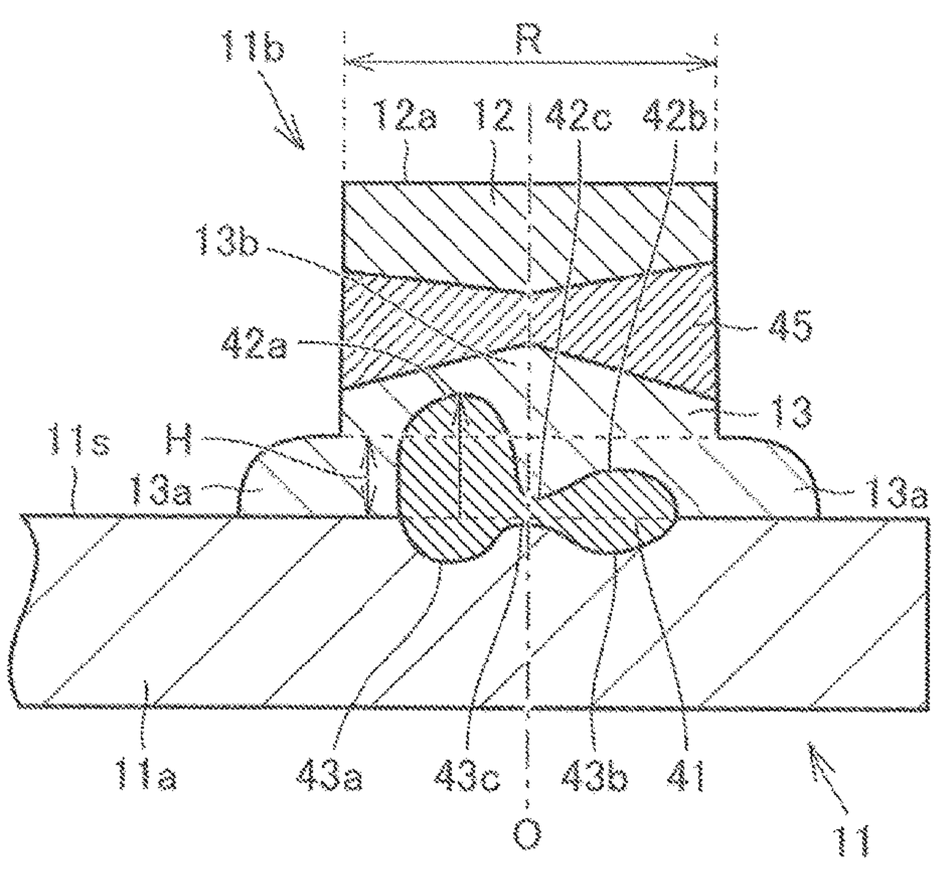
(57) **ABSTRACT**

A spark plug is provided with a center electrode and a ground electrode. The ground electrode includes an electrode tip, an electrode base material, an intermediate member and a first melt portion. The intermediate member is disposed between the electrode tip and the electrode base material. The first melt portion contains components of the electrode base material and the intermediate member, and is disposed at least at a part of the boundary between the electrode base material and the intermediate member. In a cross section including the axis of the ground electrode, the boundary line between the intermediate member and the first melt portion has at least two first projection portions projecting toward the electrode tip side, and the boundary line between the electrode base material and the first melt portion has at least two second projection portions projecting toward the opposite side of the first projection portions.

2 Claims, 6 Drawing Sheets



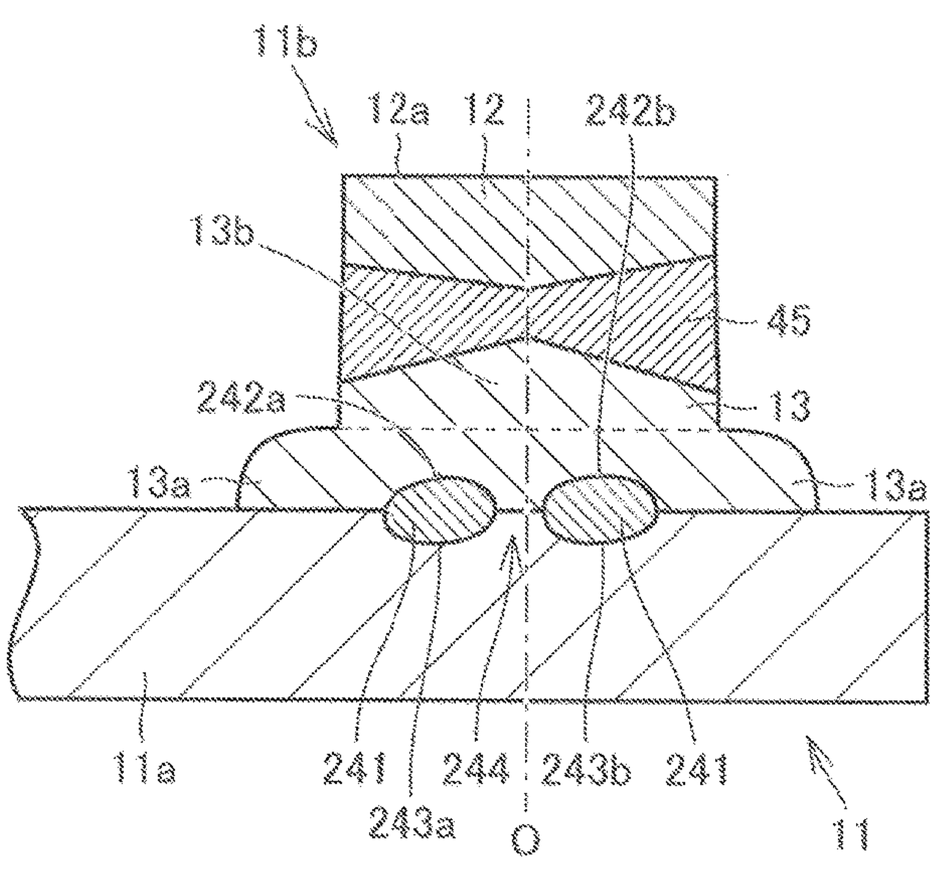


FIG. 1

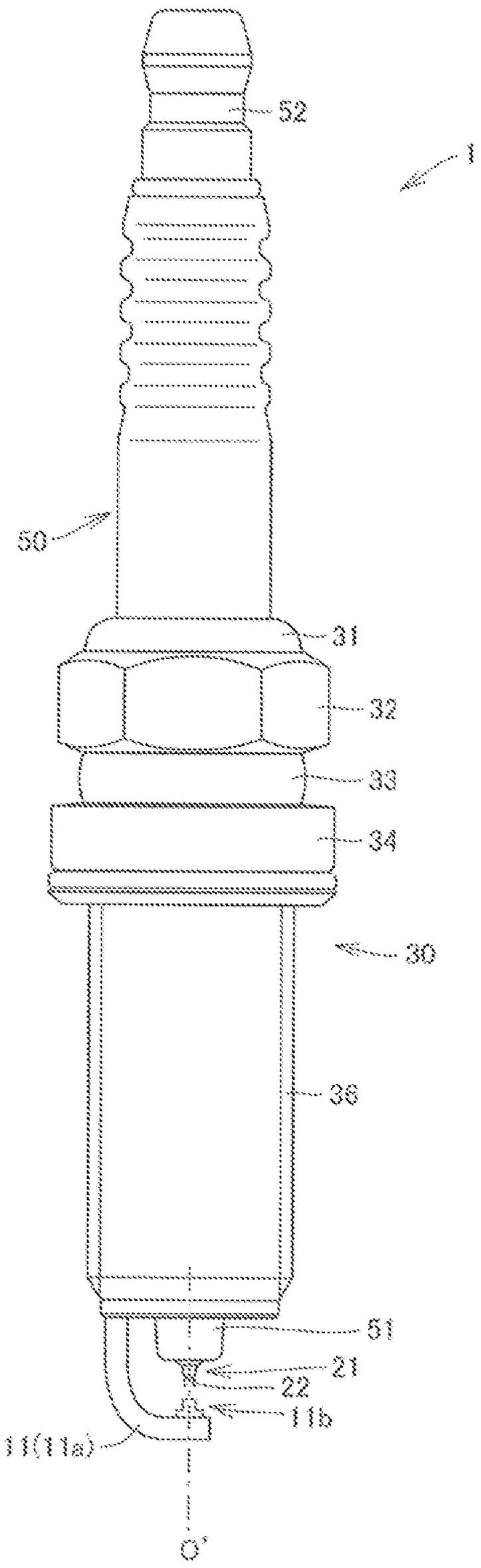


FIG. 2

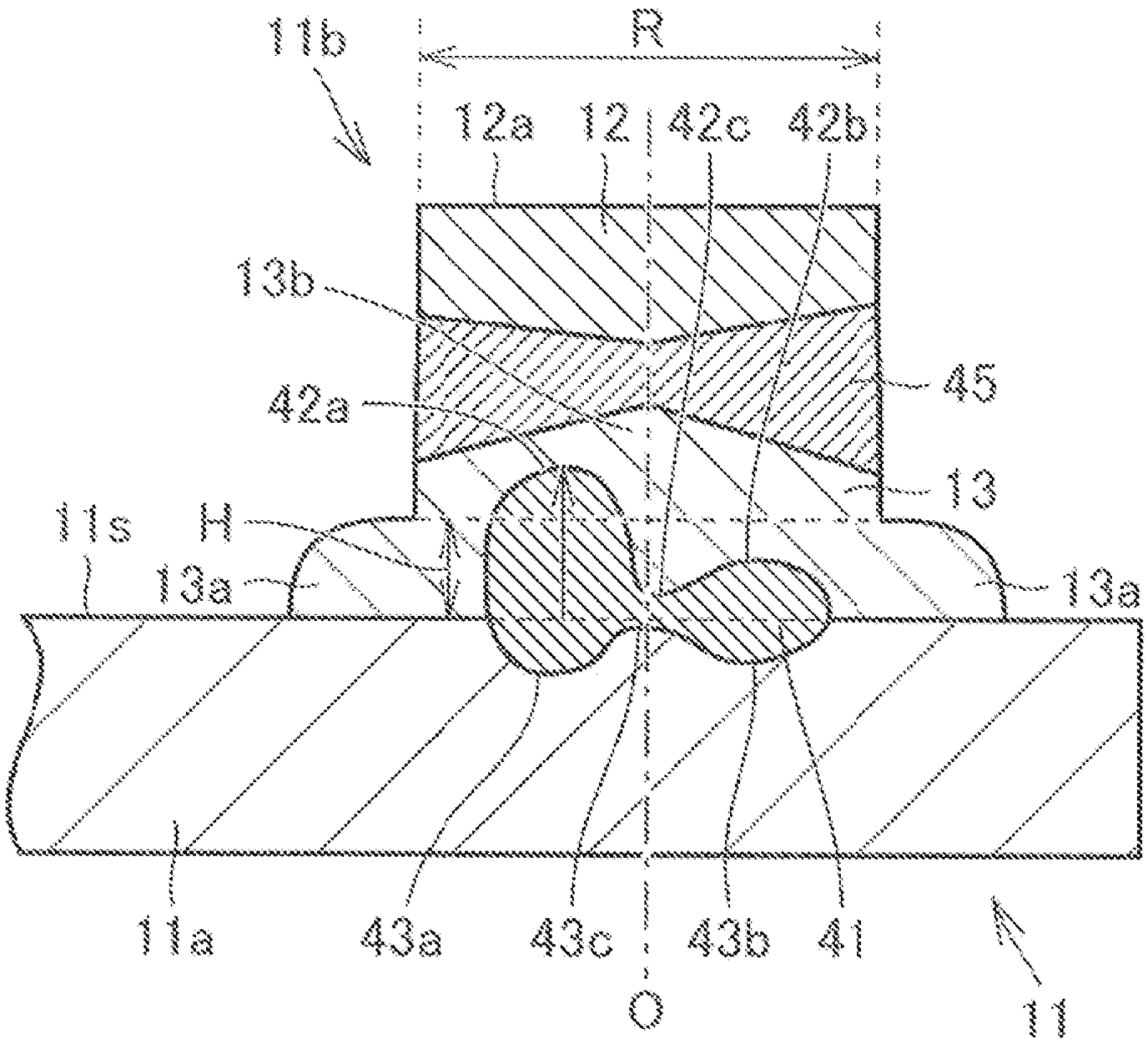

11b
R
12a
12
42c
42b
13b
42a
45
13
11s
H
13a
13a
11a
43a
43c
O
43b
41
11

FIG. 3A

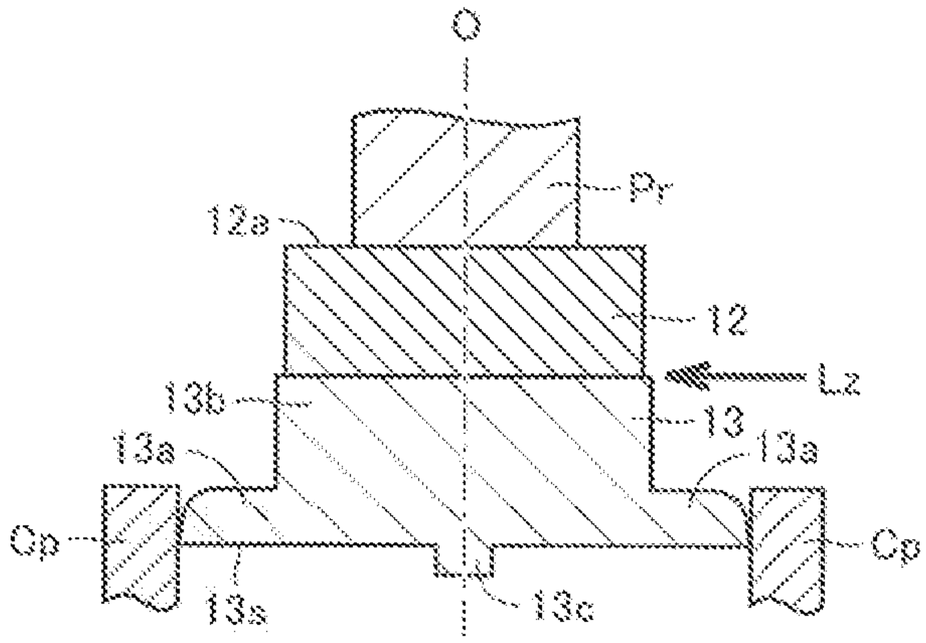

Pr
12a
12
Lz
13b
13
13a
13a
Cp
Cp
13s
13c

FIG. 3B

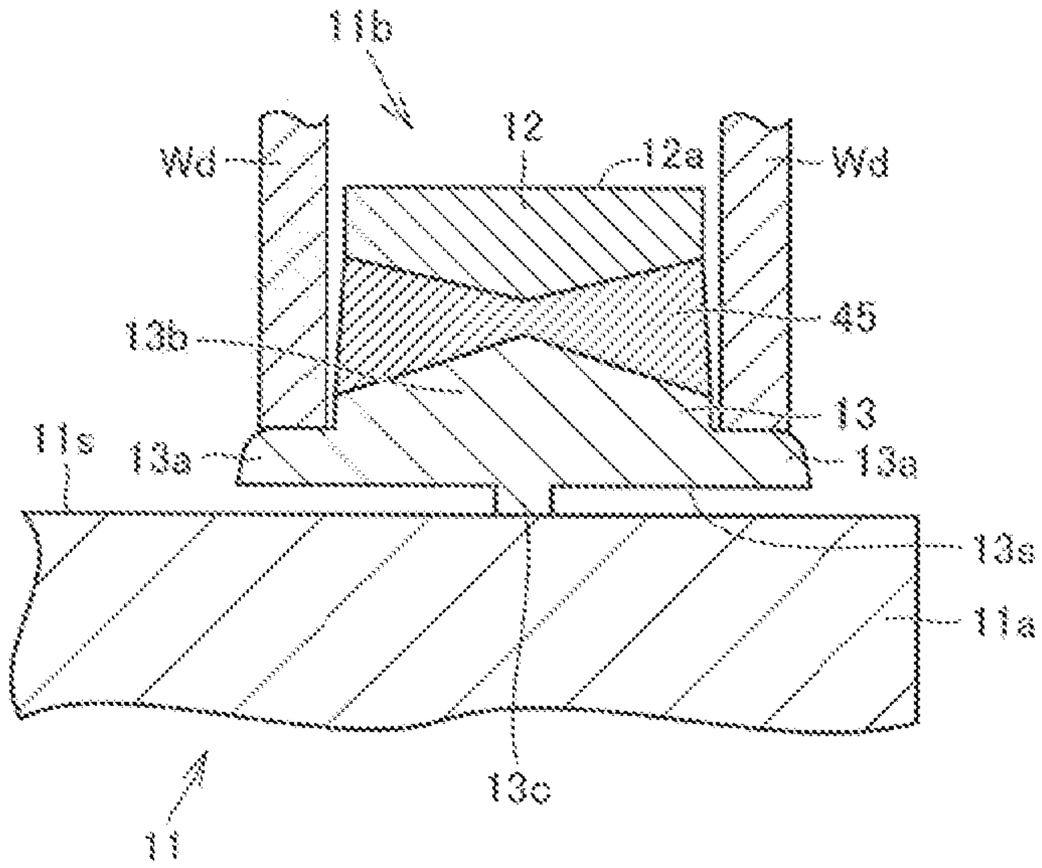

11b
12
12a
Wd
Wd
45
13b
13
11s
13a
13a
13s
11a
13c
11

FIG. 4A

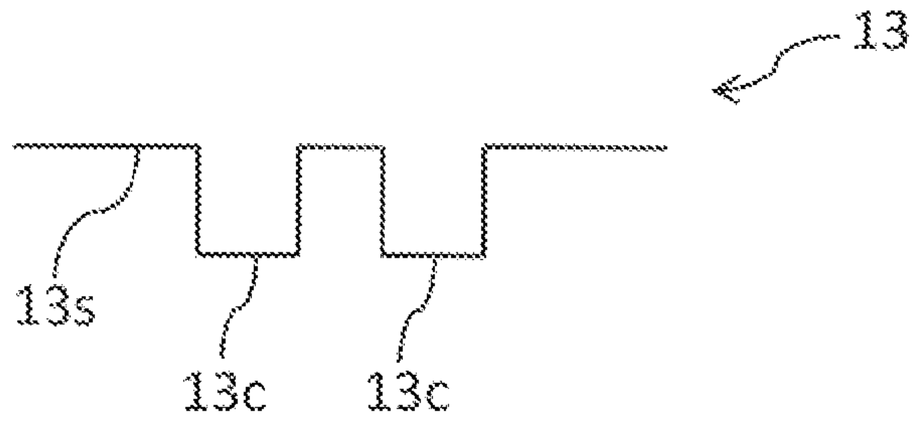


FIG. 4B

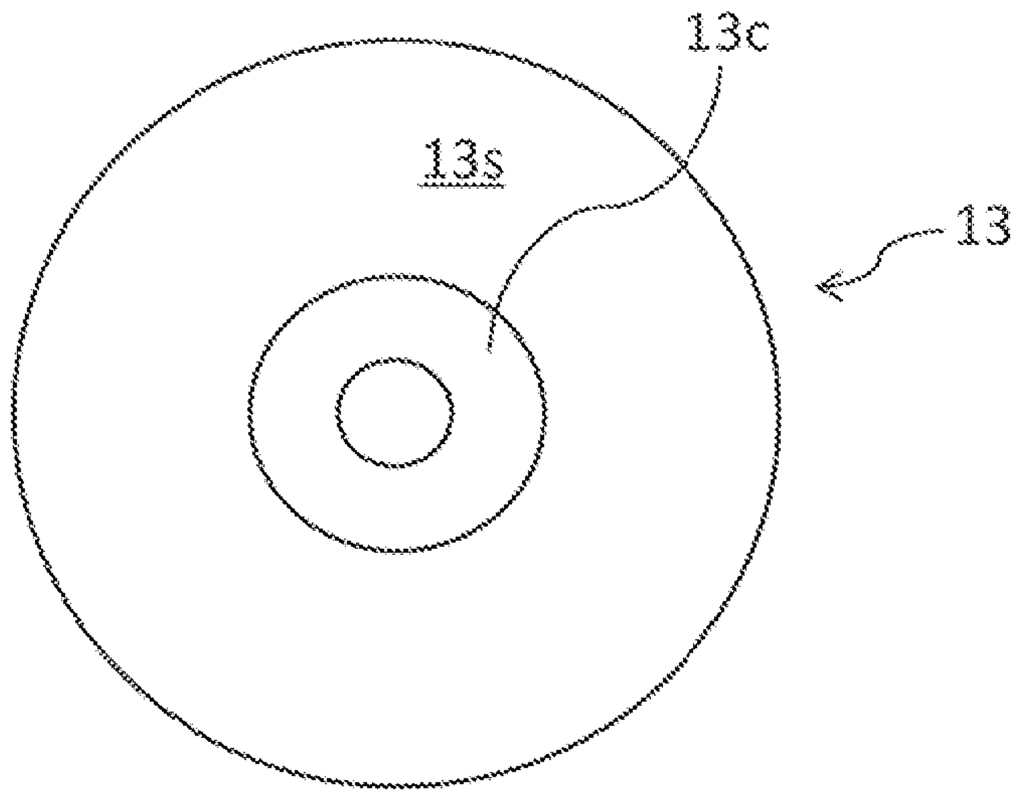


FIG. 5

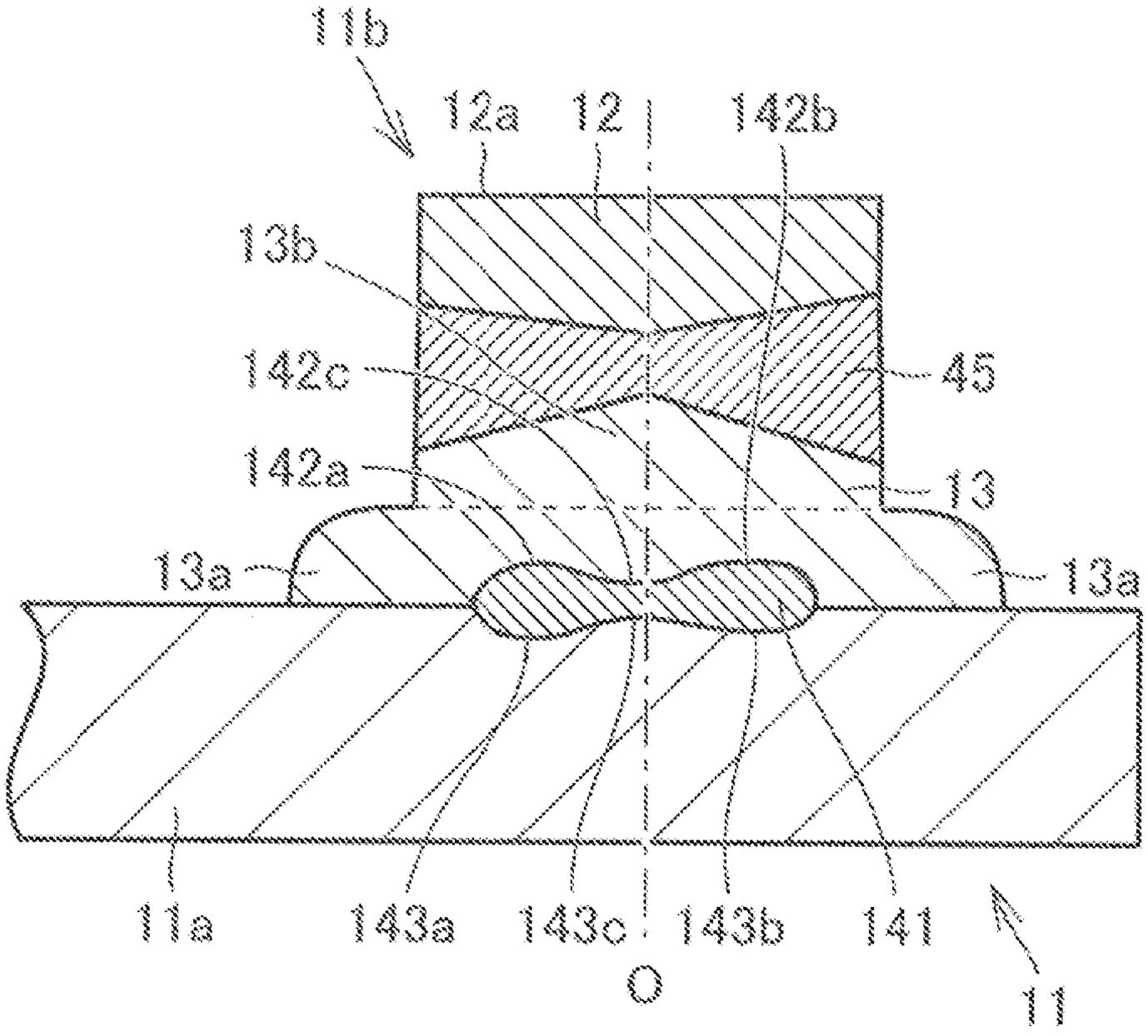
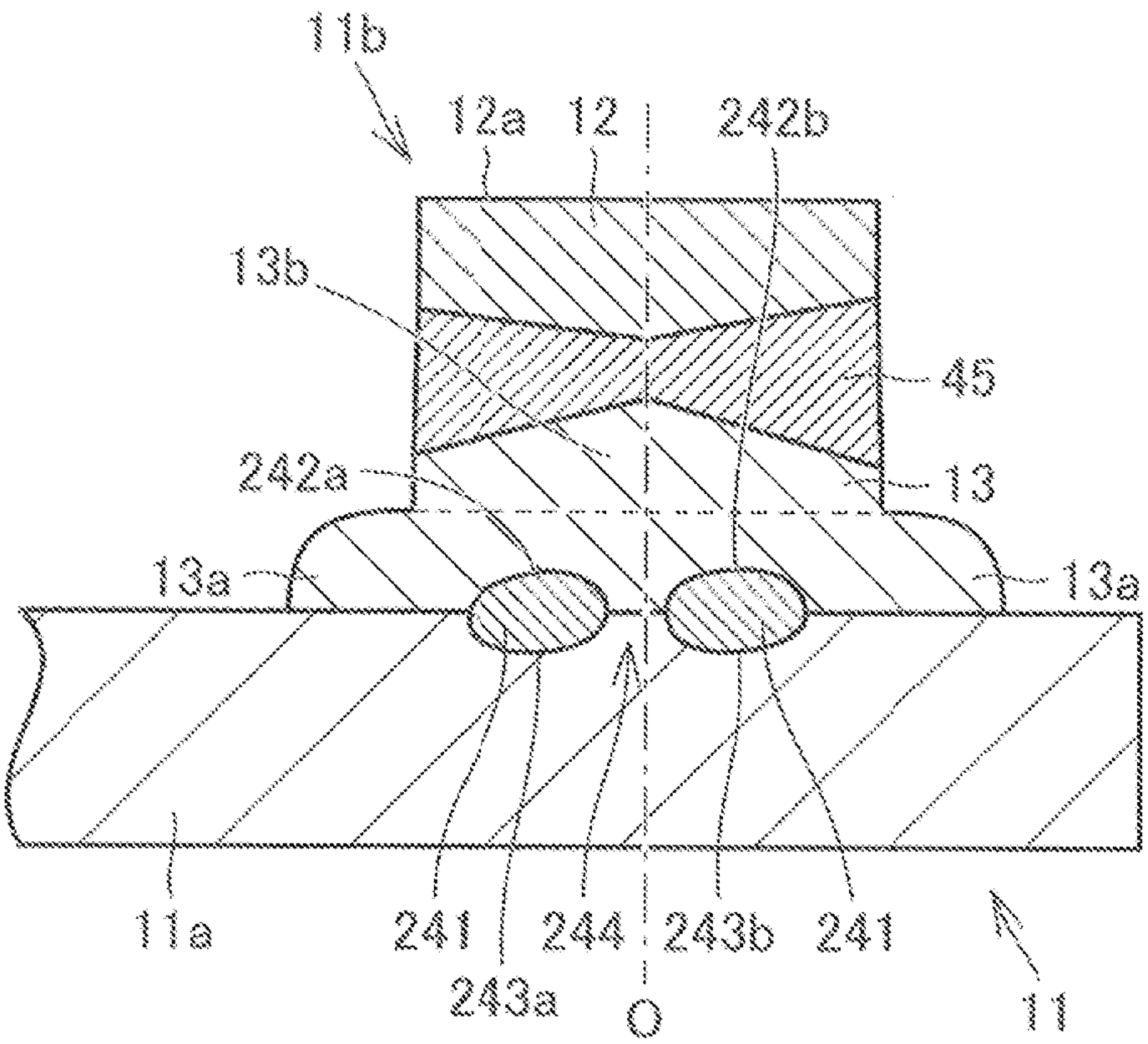

11b
12a
12
142b
13b
142c
45
142a
13
13a
13a
11a
143a
143c
O
143b
141
11

FIG. 6


11b
12a
12
242b
13b
45
242a
13
13a
13a
11a
241
244
243b
241
243a
O
11

SPARK PLUG

BACKGROUND

The present invention relates to a spark plug used for an internal combustion engine.

As an ignition means of an internal combustion engine such as an engine for an automobile, a spark plug is used. As a structure for generating spark discharge, the spark plug is provided with a center electrode and a ground electrode. For example, the surfaces of the center electrode and the ground electrode which face each other are provided with respective electrode tips made of noble metal material in order to improve ignitability of the spark plug.

In some spark plugs, the configurations of the center electrode and the ground electrode are devised to reduce the amount of use of noble metal. For example, in International Patent Application No. 2017/077688 (hereinafter is referred to as "WO2017/077688"), a spark plug is disclosed in which in at least one of a center electrode and a ground electrode, a noble metal tip is attached on a ground electrode base material via an intermediate member.

The ground electrode of the spark plug in WO2017/077688 is provided with a ground electrode base material 31, a noble metal tip 351, an intermediate member 353 and a first melt portion 352. The first melt portion 352 is formed, by laser welding, between the noble metal tip 351 and the intermediate member 353. The first melt portion 352 is a portion obtained by melting and solidifying a component of the noble metal tip 351 and a component of the intermediate member 353. In addition, a second melt portion 354 is formed at least at the position of the intersection with the axis of the noble metal tip 351 between the ground electrode base material 31 and the intermediate member 353. The second melt portion 354 is a portion obtained by melting and solidifying, by resistance welding, a component of the ground electrode base material 31 and a component of the intermediate member 353.

In this way, by fixing the noble metal tip to the ground electrode base material via the intermediate member, the joining strength of the noble metal tip can be improved, while reducing the amount of use of the noble metal tip made of a relatively expensive material. However, there is some room for improvement in the configuration of the ground electrode to increase the joining strength between the ground electrode base material and the intermediate member.

SUMMARY

In view of the foregoing, an object of the present invention is to provide a configuration of a melt portion which is capable of further increasing the joining strength between a ground electrode base material and an intermediate member in a spark plug.

The present invention is one for solving at least a part of the above problem, and it can be realized by the following aspect.

A spark plug comprises: a center electrode; and

a ground electrode, wherein the ground electrode includes: an electrode tip having a facing surface facing a distal end portion of the center electrode; an electrode base material supporting the electrode tip; an intermediate member disposed between the electrode tip and the electrode base material; and a melt portion containing a component of the electrode base material and a component of the intermediate member, and disposed at least at a part of a boundary between the electrode base material and the intermediate member, and wherein a part of the melt portion which is formed at a position radially inside the facing surface includes, when observing a cross section including an axis of the ground electrode, a boundary line between the intermediate member and the melt portion which has at least two first projection portions projecting toward an electrode tip side and a boundary line between the electrode base material and the melt portion which has at least two second projection portions projecting toward an opposite side of the first projection portions.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a side view showing the appearance of a spark plug according to an embodiment.

FIG. **2** is a sectional view schematically showing the internal configuration of a ground electrode of the spark plug according to a first embodiment.

FIGS. **3**A and **3**B each are a schematic diagram showing the manufacturing process of a projection part of the ground electrode in order.

FIG. **4**A is a sectional view schematically showing an example of a projection formed on the end surface of an intermediate member before welding, and FIG. **4**B is a plane view schematically showing an example of the projection formed on the end surface of the intermediate member before welding.

FIG. **5** is a sectional view schematically showing the internal configuration of the ground electrode of the spark plug according to a second embodiment.

FIG. **6** is a sectional view schematically showing the internal configuration of the ground electrode of the spark plug according to a third embodiment.

DETAILED DESCRIPTION

In the following, while referencing the drawings, embodiments of the present invention will be explained. In the following explanation, the same symbols are applied to the same components, and their names and functions are also the same. Redundant explanation is therefore omitted.

First Embodiment

In the present embodiment, as an example, a spark plug **1** will be explained.

(Whole Configuration of Spark Plug)

First, the whole configuration of the spark plug **1** will be explained while referencing FIG. **1**. The spark plug **1** is provided with an insulator **50** and a main metal fitting **30**. In FIG. **1**, the lower side on the paper is referred to as the distal end side of the spark plug **1**, and the upper side on the paper is referred to as the rear end side of the spark plug **1**. In addition, in FIG. **1**, the axis of the spark plug **1** is shown by "O'". In the following, the direction parallel to the axis O' is referred to as an axial direction, and the radial direction of a circle with the axis O' as a center which is positioned on a plane vertical to the axis O' is simply referred to as a radial direction, and the circumferential direction of this circle is simply referred to as a circumferential direction.

The insulator **50** is a substantially cylindrical member extending in the longitudinal direction of the spark plug **1**. The insulator **50** is made of a material excellent in insulation, heat resistance and thermal conductivity. The insulator **50** is made of, for example, an alumina-based ceramic. One end portion (distal end portion) of the insulator **50** is

provided with a center electrode **21**. In addition, the other end portion (rear end portion) of the insulator **50** is attached with a terminal metal fitting **52**.

The center electrode **21** is held in an axial hole of the insulator **50** in a state in which the distal end portion (electrode distal end portion **22**) of the center electrode **21** projects from a distal end portion **51** of the insulator **50**. The center electrode **21** has a substantially columnar shape, and the distal end part thereof is formed in a tapered shape such that the diameter is gradually reduced toward the electrode distal end portion **22**. The electrode distal end portion **22** is provided to the distal end of the center electrode **21**, and has a substantially columnar shape having the same diameter as the reduced diameter of the distal end part of the center electrode **21**. The electrode distal end portion **22** is disposed so as to substantially correspond to the axis O'.

The center electrode **21** is made of a metal material, as a base material, such as an Ni-based alloy containing Ni (nickel) as a main component. As an alloy element to be added to the Ni-based alloy, for example, Al (aluminum) can be cited. The center electrode **21** may have, inside thereof, a core material formed from a metal excellent in thermal conductivity made of a metal material such as Cu (copper) and Cu alloy.

The electrode distal end portion **22** can be formed by, for example, a noble metal tip formed in a columnar shape, and is joined to the distal end of the center electrode **21** by, for example, welding. The noble metal tip contains one kind of a noble metal selected from, for example, Pt, Rh, Ir and Ru, and the content ratio of the noble metal is 50 wt % or greater.

The main metal fitting **30** is a cylindrical member fixed to a screw hole of an internal combustion engine. In the present embodiment, the main metal fitting **30** has a substantially cylindrical shape, and is provided so as to cover a part of the insulator **50**. The main metal fitting **30** is made of a metal material having conductivity. As such a metal material, a metal material containing, as a main component, a low carbon steel or iron can be cited. The main metal fitting **30** mainly includes a caulking portion **31**, a tool engagement portion **32**, a curved portion **33**, a seat portion **34**, a barrel portion **36**, and the like.

The caulking portion **31** is a portion curved toward the insulator **50** side in the rear end side of the main metal fitting **30**. The tool engagement portion **32** is a portion connected to the distal end side of the caulking portion **31**, and engaging with a tool such as a wrench used when the main metal fitting **30** is attached to a screw hole of the internal combustion engine (cylinder head). The seat portion **34** is positioned more on the distal end side than the tool engagement portion **32**, and projects radially outward from the main metal fitting **30**.

The curved portion **33** is a thin portion connecting the tool engagement portion **32** with the seat portion **34**. The barrel portion **36** is positioned on the distal end side of the seat portion **34**, and is formed with, on the outer periphery thereof, a screw part. A ring-shaped gasket is disposed between the seat portion **34** and the screw part of the barrel portion **36**. When the spark plug **1** is attached to the internal combustion engine, the screw groove (not shown) formed on the outer periphery of the barrel portion **36** is screwed to the screw hole of the internal combustion engine. At this time, the ring-shaped gasket is sandwiched by the seat portion **34** and the cylinder head, thereby ensuring airtightness in the screw hole.

In addition, the main metal fitting **30** is joined with a ground electrode **11**. The ground electrode **11** mainly includes an electrode base material **11***a* and a projection part **11***b*. The electrode base material **11***a* has a bar shape curved in a substantially L shape. The base end portion of the electrode base material **11***a* is joined to the distal end surface of the barrel portion **36** of the main metal fitting **30**. The distal end portion of the electrode base material **11***a* faces the electrode distal end portion **22** of the center electrode **21**.

The electrode base material **11***a* is made of a metal material such as an Ni-based alloy containing Ni (nickel) as a main component. As an alloy element to be added to the Ni-based alloy, for example, Mn (manganese), Cr (chromium), Al (aluminum) and Fe (iron) can be cited. The ground electrode **11** may have, inside thereof, a core material formed from a metal excellent in thermal conductivity made of a metal material such as Cu (copper) and Cu alloy.

As a metal material used for the electrode base material **11***a*, specifically, Inconel (registered trade mark) and an NCF material specified by JIS G-4901 can be cited. These metal materials have oxidation consumption resistance.

The projection part **11***b* is disposed on the distal end side of the electrode base material **11***a*, so as to project toward the electrode distal end portion **22** side of the center electrode **21**. The distal end of the projection part **11***b* is a facing surface (specifically, a top surface **12***a*) facing the electrode distal end portion **22** of the center electrode **21**. The projection part **11***b* projects toward the electrode distal end portion **22** side so as to substantially correspond to the axis O'.

Similar to the electrode distal end portion **22** of the center electrode **21**, the projection part **11***b* is composed of an electrode tip (specifically, an electrode tip **12**) containing noble metal and the like.

(Configuration of Projection Part of Ground Electrode)

Next, the configuration around the projection part **11***b* of the ground electrode **11** will be explained. In FIG. **2**, the configuration in a cross section of the projection portion **11***b* of the ground electrode **11** is shown. FIG. **2** is a drawing showing the configuration of an arbitrary cross section including an axis O of the substantially columnar projection part **11***b*. In addition, the axis O of the projection part **11***b* substantially corresponds to the axis O' of the spark plug **1**.

The projection part **11***b* of the ground electrode **11** is formed on the electrode base material **11***a*. The electrode base material **11***a* supports the projection part **11***b* composed of the electrode tip **12** and the like.

The projection part **11***b* is mainly composed of the electrode tip **12**, an intermediate member **13**, a first melt portion **41** and a second melt portion **45**.

The electrode tip **12** can be formed by, for example, a noble metal tip formed in a columnar shape. The electrode tip **12** forms the distal end portion of the projection part **11***b*, and has a top surface **12***a* (facing surface) facing the electrode distal end portion **22** of the center electrode **21**. In addition, the length in the radial direction of the electrode tip **12** is set as a diameter R (see FIG. **2**). Similar to the electrode distal end portion **22** of the center electrode **21**, the electrode tip **12** contains one kind of a noble metal selected from, for example, Pt, Rh, Ir and Ru, and the content ratio of the noble metal is 50 wt % or greater.

The intermediate member **13** is disposed between the electrode tip **12** and the electrode base material **11***a*. In the present embodiment, the intermediate member **13** is disposed on a surface **11***s* of the electrode base material **11***a* on the side facing the center electrode **21**. The intermediate member **13** is made of a metal material such as an Ni-based alloy containing Ni (nickel) as a main component. As an alloy element to be added to the Ni-based alloy, for example, Mn (manganese), Cr (chromium), Al (aluminum) and Si

(silicon) can be cited. The intermediate member **13** may be formed by using the same material as or different material from that of the electrode base material **11***a* of the ground electrode **11**.

The intermediate member **13** mainly includes a body portion **13***b* and a flange portion **13***a*. The body portion **13***b* is positioned on the electrode tip **12** side, and has a substantially columnar shape. The flange portion **13***a* is positioned on the electrode base material **11***a* side, and is provided such that the diameter of the body portion **13***b* is expanded in the radial direction. In addition, in the flange portion **13***a*, the length, in the axial direction, from the surface **11***s* of the electrode base material **11***a* to the boundary between the flange portion **13***a* and the body portion **13***b* is set as a height H of the flange portion **13***a* (see FIG. **2**).

As will be mentioned below, the electrode tip **12** and the intermediate member **13** are joined to the electrode base material **11***a* of the ground electrode **11** by welding (for example, laser welding or resistance welding). In the joining process by the welding, the first melt portion (melt portion) **41** is formed at the boundary between the electrode base material **11***a* and the intermediate member **13**, and the second melt portion **45** is formed at the boundary between the electrode tip **12** and the intermediate member **13**.

The first melt portion **41** is formed at least at a part of the boundary between the electrode base material **11***a* and the intermediate member **13**. The first melt portion **41** contains a component of the electrode base material **11***a* and a component of the intermediate member **13**. That is, the first melt portion **41** is made of an alloy of a metal material contained in the electrode base material **11***a* and a metal material contained in the intermediate member **13**. The first melt portion **41** is formed by, for example, resistance welding.

The first melt portion **41** is formed in an area radially inside the diameter R of the top surface **12***a* of the electrode tip **12**. As will be mentioned below, the shape and the size of the first melt portion **41** can be changed by properly changing the shape and the size of a projection **13***c* (see FIG. **3**A) formed in the intermediate member **13** before welding, or conditions of the resistance welding.

In FIG. **2**, the internal configuration of the projection part **11***b* of the ground electrode **11** is shown. FIG. **2** is a drawing schematically showing the state of a cross section including the axis O of the projection part **11***b* of the ground electrode **11**. Such a state of the cross section can be observed by using, for example, an optical microscope or an electron microscope.

In an arbitrary cross section including the axis O of the projection part **11***b*, the first melt portion **41** includes, in the boundary with the intermediate member **13**, two first projection portions **42***a* and **42***b* projecting toward the electrode tip **12** side, and a first recess portion **42***c* positioned between these two first projection portions **42***a* and **42***b*. The first projection portion **42***a* and the first projection portion **42***b* are formed so as to be circumferentially continued along the circumference of a circle with the axis O as a center. In addition, the first recess portion **42***c* is provided in an area including the axis O.

Further, in an arbitrary cross section including the axis O of the projection part **11***b*, the first melt portion **41** includes, in the boundary with the electrode base material **11***a*, two second projection portions **43***a* and **43***b* projecting toward the electrode base material **11***a* side (that is, the opposite side of the first projection portions **42***a* and **42***b*), and a second recess portion **43***c* positioned between these two second projection portions **43***a* and **43***b*. The second projection portion **43***a* and the second projection portion **43***b* are formed so as to be circumferentially continued along the circumference of a circle with the axis O as a center. In addition, the second recess portion **43***c* is provided in an area including the axis O.

In an arbitrary cross section including the axis O of the projection part **11***b*, the first melt portion **41** includes the first projection portions **42***a* and **42***b* projecting toward the electrode tip **12** side and the first recess portion **42***c* provided therebetween, thereby increasing the surface area of the first melt portion **41** in the boundary between the first melt portion **41** and the intermediate member **13**. Further, in an arbitrary cross section including the axis O of the projection part **11***b*, the first melt portion **41** includes the second projection portions **43***a* and **43***b* projecting toward the electrode base material **11***a* side and the second recess portion **43***c* provided therebetween, thereby increasing the surface area of the first melt portion **41** in the boundary between the first melt portion **41** and the electrode base material **11***a*.

With this, the joining strength between the electrode base material **11***a* and the intermediate member **13** which are joined to each other via the first melt portion **41** can be increased. In addition, the first melt portion **41** is formed in the area radially inside the diameter R of the top surface **12***a* of the electrode tip **12**, thereby further increasing the joining strength between the electrode base material **11***a* and the intermediate member **13**.

In addition, in the present embodiment, the height of at least one of the two first projection portions **42***a* and **42***b* (in FIG. **2**, the first projection portion **42***a*) projecting toward the electrode tip **12** side is higher than the height H of the flange portion **13***a*. Here, as shown by an arrow in FIG. **2**, the height of the first projection portion **42***a* is a length from the virtual extension surface (shown by a broken line in FIG. **2**) of the surface **11***s* of the electrode base material **11***a* to the top of the first projection portion **42***a* in the axial direction.

Since the height of the first projection portion **42***a* is higher than that of the flange portion **13***a*, a structure in which the intermediate member **13** hardly moves in the radial direction when a force in the radial direction is applied to the projection part **11***b* of the ground electrode **11** can be obtained.

The second melt portion **45** is disposed at least at a part of the boundary between the electrode tip **12** and the intermediate member **13**. In the present embodiment, the second melt portion **45** is formed in the whole area of the boundary between the electrode tip **12** and the intermediate member **13**. In other words, the second melt portion **45** is disposed between the electrode tip **12** and the intermediate member **13**. The second meld portion **45** contains a component of the electrode tip **12** and a component of the intermediate member **13**. That is, the second melt portion **45** is made of an alloy of a metal material contained in the electrode tip **12** and a metal material contained in the intermediate member **13**. The second melt portion **45** is formed by, for example, laser welding.

Although not shown in FIG. **2**, in the boundary between the electrode base material **11***a* and the intermediate member **13**, a melt portion different from the first melt portion **41** may be formed at a position radially outside the diameter R of the top surface **12***a* of the electrode tip **12**.

(Manufacturing Method for Ground Electrode)

Next, a manufacturing method for the spark plug **1** will be explained. Here, a manufacturing method of the projection part **11***b* of the ground electrode **11** will be mainly explained. In the manufacturing method of the spark plug **1**, a well

know manufacturing method can be applied to parts other than the projection part **11***b* of the ground electrode **11**.

In FIG. **3**A and FIG. **3**B, a formation process of the projection part **11***b* is shown in order. When manufacturing the projection part **11***b*, the electrode tip **12** before welding and the intermediate member **13** before welding are prepared. The electrode tip **12** before welding has a substantially columnar shape.

The intermediate member **13** before welding includes the body portion **13***b*, the flange portion **13***a* and the projection **13***c*. The body portion **13***b* has a substantially columnar shape. The flange portion **13***a* is provided to one end portion of the substantially columnar body portion **13***b* such that the diameter of the body portion **13***b* is expanded. That is, the diameter of the flange portion **13***a* is larger than that of the body portion **13***b*. The projection **13***c* is a projection projecting from one end surface (an end surface **13***s* positioned on the side in which the flange portion **13***a* is provided) of the substantially columnar body portion **13***b*.

The electrode tip **12** and the intermediate member **13** are joined to the electrode base material **11***a* by performing, for example, welding processing such as laser welding and resistance welding.

First, the electrode tip **12** and the intermediate member **13** are joined to each other by laser welding. Specifically, as shown in FIG. **3**A, the flange portion **13***a* of the intermediate member **13** is fixed by using a fastening tool Cp, and then the electrode tip **12** is placed on the other end surface (end surface on the opposite side of the end surface **13***s*) of the body portion **13***b* of the intermediate member **13**. At this time, the axis of the substantially columnar electrode tip **12** and the axis of the substantially columnar body portion **13***b* of the intermediate member **13** are positioned on the axis O.

After that, in a state in which the top surface **12***a* of the electrode tip **12** is pressed by using a predetermined pressing member Pr, a laser Lz vertical to the axis O is irradiated to the contact part between the electrode tip **12** and the intermediate member **13** from the outside to the inside in the radial direction. The laser Lz is irradiated to the contact part between the electrode tip **12** and the intermediate member **13** by using, for example, an irradiation device such as a fiber laser irradiation device.

Then, with respect to the irradiation device of the laser Lz, the electrode tip **12** and the intermediate member **13** are relatively rotated about the axis O, so as to irradiate the laser Lz to the entire periphery of the contact part between the electrode tip **12** and the intermediate member **13**. With this, the second melt portion **45** having a shape shown in FIG. **3**B is formed between the electrode tip **12** and the intermediate member **13**, and the electrode tip **12** and the intermediate member **13** are joined to each other.

At this time, the shape of the second melt portion **45** can be controlled by adjusting conditions such as the energy or the condensing position of the laser Lz, the rotation speed of the electrode tip **12** and the intermediate member **13**, and the pressure generated by the pressing member Pr. For example, by increasing the rotation speed and the energy of the laser Lz, it is possible to reduce the difference between the thickness on the axis O and the thickness in the outer peripheral surface of the second melt portion **45**.

Next, as shown in FIG. **3**B, the intermediate member **13** joined with the electrode tip **12** is fixed, by resistance welding, to the surface **11***s* of the electrode base material **11***a* of the ground electrode **11**. At this time, in a state in which, by a cylindrical welding electrode Wd, the surface on the opposite side of the end surface **13***s* of the flange portion **13***a* is pressed, electric current for welding flows between the electrode base material **11***a* and the intermediate member **13**, and the resistance welding is performed. Since the resistance welding is started in a state in which the surface **11***s* of the electrode base material **11***a* is brought into contact with the projection **13***c* of the intermediate member **13**, first, the electric current is concentrated to the projection **13***c*. Consequently, the projection **13***c* and a part of the electrode base material **11***a* which comes in contact with the projection **13***c* are melt, and the first melt portion **41** is formed.

After that, the end surface **13***s* of the intermediate member **13** comes in contact with the surface **11***s* of the electrode base material **11***a*, and the resistance welding of the end surface **13***s* of the intermediate member **13** and the electrode base material **11***a* is performed. Consequently, the first melt portion **41** shown in FIG. **2** is formed, and the electrode tip **12** and the intermediate member **13** are melted and fixed onto the electrode base material **11***a*.

The shape and the size of the first melt portion **41** can be controlled by adjusting the shape or the size of the projection **13***c*, or conditions for the resistance welding such as the magnitude of the electric current and the pressure of the welding electrode Wd.

For example, the longer the length in the axial direction of the projection **13***c* becomes, the longer the length in the axial direction of the first melt portion **41** (that is, the heights of the first projection portions **42***a* and **42***b* and the second projection portions **43***a* and **43***b*) becomes, and the longer the length in the radial direction vertical to the axial direction of the projection **13***c* becomes, the longer the length in the radial direction of the first melt portion **41** becomes.

In FIG. **4**A and FIG. **4**B, an example of the shape of the projection **13***c* formed to the end surface **13***s* of the intermediate member **13** before the welding is shown. The projection **13***c* shown in FIG. **4**A and FIG. **4**B is formed in a doughnut shape in the middle part of the end surface **13***s*. For example, by using the intermediate member **13** including the projection **13***c* having such a shape, the first melt portion **41** having the first projection portions **42***a* and **42***b* and the second projection portions **43***a* and **43***b* shown in FIG. **2** can be formed.

Summary of First Embodiment

As mentioned above, the spark plug **1** according to the present embodiment is provided with the center electrode **21** and the ground electrode **11**. The ground electrode **11** mainly includes the electrode tip **12**, the electrode base material **11***a* for supporting the electrode tip **12**, the intermediate member **13**, and the first melt portion **41**. The intermediate member **13** is disposed between the electrode tip **12** and the electrode base material **11***a*. The first melt portion **41** contains a component of the electrode base material **11***a* and a component of the intermediate member **13**, and is disposed at least at a part of the boundary between the electrode base material **11***a* and the intermediate member **13**. When the cross section including the axis O of the ground electrode **11** is observed, the boundary line between the intermediate member **13** and the first melt portion **41** includes at least the two first projection portions **42***a* and **42***b* projecting toward the electrode tip **12** side, and the boundary line between the electrode base material **11***a* and the first melt portion **41** includes at least the two second projection portions **43***a* and **43***b* projecting toward the opposite side of the first projection portions **43***a* and **43***b*.

According to the above configuration, the electrode tip **12** is fixed to the electrode base material **11***a* via the intermediate member **13** disposed therebetween, thereby firmly

joining the electrode tip **12** onto the electrode base material **11***a* while reducing the amount of use of a relatively expensive electrode tip containing a noble metal.

In addition, in an arbitrary cross section including the axis O of the projection part **11***b*, the first melt portion **41** includes at least the two first projection portions **42***a* and **42***b* projecting toward the electrode tip **12** side, thereby increasing the surface area of the first melt portion **41** in the boundary between the first melt portion **41** and the intermediate member **13**. Further, in an arbitrary cross section including the axis O of the projection part **11***b*, the first melt portion **41** includes at least the two second projection portions **43***a* and **43***b* projecting toward the electrode base material **11***a* side, thereby increasing the surface area of the first melt portion **41** in the boundary between the first melt portion **41** and the electrode base material **11***a*.

According to the above configuration, it is possible to increase the joining strength between the electrode base material **11***a* and the intermediate member **13** which are joined to each other via the first melt portion **41**.

Second Embodiment

Next, a spark plug **1** according to a second embodiment will be explained. In the spark plug **1** according to the second embodiment, the configuration of a projection part **11***b* of a ground electrode **11** is different from that of the projection part **11***b* of the ground electrode **11** in the first embodiment. In the spark plug **1** according to the second embodiment, the configuration similar to that of the spark plug **1** according to the first embodiment can be applied to parts other than the projection part **11***b*.

In FIG. **5**, the configuration in cross section of the projection part **11***b* of the ground electrode **11** provided to the spark plug **1** according to the second embodiment is shown.

The projection part **11***b* of the ground electrode **11** is formed on an electrode base material **11***a*. The projection part **11***b* is mainly composed of an electrode tip **12**, an intermediate member **13**, a first melt portion **141** and a second melt portion **45**. In these components, the configuration similar to the first embodiment can be applied to the electrode tip **12**, the intermediate member **13** and the second melt portion **45**.

In the spark plug **1** according to the present embodiment, the shape of the first melt portion **141**, more specifically, the shape of the boundary surface between the intermediate member **13** and the first melt portion **141** is different from the shape of the first melt portion **41** in the first embodiment.

The first melt portion **141** is disposed at least at a part of the boundary between the electrode base material **11***a* and the intermediate member **13**. Similar to the first embodiment, the first melt portion **141** contains a component of the electrode base material **11***a* and a component of the intermediate member **13**. The first melt portion **141** is formed by, for example, resistance welding.

As shown in FIG. **5**, in an arbitrary cross section including an axis O of the projection part **11***b*, the first melt portion **141** includes, in the boundary with the intermediate member **13**, two first projection portions **142***a* and **142***b* projecting toward the electrode tip **12** side, and a first recess portion **142***c* positioned between these two first projection portions **142***a* and **142***b*.

In addition, as shown in FIG. **5**, in an arbitrary cross section including the axis O of the projection part **11***b*, the first melt portion **141** includes, in the boundary with the electrode base material **11***a*, two second projection portions **143***a* and **143***b* projecting toward the electrode base material **11***a* side (that is, the opposite side of the first projection portions **142***a* and **142***b*), and a second recess portion **143***c* positioned between these two second projection portions **143***a* and **143***b*.

In the present embodiment, the heights of the two first projection portions **142***a* and **142***b* shown in FIG. **5** are substantially the same as each other. In addition, the heights of these two first projection portions **142***a* and **142***b* are lower than the height H of the flange portion **13***a*. In this way, the first melt portion **141** has a substantially disk shape having, in the middle thereof, a recess (that is, the first recess portion **142***c* and the second recess portion **143***c*).

In the spark plug **1** according to the present embodiment, in an arbitrary cross section including the axis O of the projection part **11***b*, the first melt portion **141** includes the first projection portions **142***a* and **142***b* projecting toward the electrode tip **12** side, and the first recess portion **142***c* provided therebetween, thereby increasing the surface area of the first melt portion **141** in the boundary between the first melt portion **141** and the intermediate member **13**. In addition, in an arbitrary cross section including the axis O of the projection part **11***b*, the first melt portion **141** includes the second projection portions **143***a* and **143***b* projecting toward the electrode base material **11***a* side, and the second recess portion **143***c* provided therebetween, thereby increasing the surface area of the first melt portion **141** in the boundary between the first melt portion **141** and the electrode base material **11***a*.

Consequently, it is possible to increase the joining strength between the electrode base material **11***a* and the intermediate member **13** which are joined to each other via the first melt portion **141**.

Third Embodiment

Next, a spark plug **1** according to a third embodiment will be explained. In the spark plug **1** according to the third embodiment, the configuration of a projection part **11***b* of a ground electrode **11** is different from that of the projection part **11***b* of the ground electrode **11** in the first embodiment. In the spark plug **1** according to the third embodiment, the configuration similar to that of the spark plug **1** according to the first embodiment can be applied to parts other than the projection part **11***b*.

In FIG. **6**, the configuration in cross section of the projection part **11***b* of the ground electrode **11** provided to the spark plug **1** according to the third embodiment is shown.

The projection part **11***b* of the ground electrode **11** is formed on an electrode base material **11***a*. The projection part **11***b* is mainly composed of an electrode tip **12**, an intermediate member **13**, a first melt portion **241** and a second melt portion **45**. In these components, the configuration similar to the first embodiment can be applied to the electrode tip **12**, the intermediate member **13** and the second melt portion **45**.

In the spark plug **1** according to the present embodiment, the shape of the first melt portion **241** is different from the shape of the first melt portion **41** in the first embodiment.

As shown in FIG. **6**, in an arbitrary cross section including an axis O of the projection part **11***b*, the first melt portion **241** includes, in the boundary with the intermediate member **13**, two first projection portions **242***a* and **242***b* projecting toward the electrode tip **12** side. The first projection portions **242***a* and **242***b* are formed so as to be circumferentially

continued with each other along the circumference of a circle with the axis O as a center.

In addition, as shown in FIG. **6**, in an arbitrary cross section including the axis O of the projection part **11***b*, the first melt portion **241** includes, in the boundary with the electrode base material **11***a*, two second projection portions **243***a* and **243***b* projecting toward the electrode base material **11***a* side (that is, the opposite side of the first projection portions **242***a* and **242***b*). The second projection portions **243***a* and **243***b* are formed so as to be circumferentially continued with each other along the circumference of a circle with the axis O as a center.

Then, the first melt portion **241** includes a penetration portion **244** between the first projection portions **242***a* and **242***b* and between the second projection portions **243***a* and **243***b* (that is, in the middle part of a circle with the axis O as a center). This penetration portion **244** is filled with the material of the intermediate member **13**. In this way, the first melt portion **241** has a substantially doughnut shape having an opening (that is, the penetration portion **244**) in the middle.

In the spark plug **1** according to the present embodiment, in an arbitrary cross section including the axis O of the projection part **11***b*, the first melt portion **241** includes the first projection portions **242***a* and **242***b* projecting toward the electrode tip **12** side, and the penetration portion **244** provided therebetween, thereby increasing the surface area of the first melt portion **241** in the boundary between the first melt portion **241** and the intermediate member **13**. In addition, in an arbitrary cross section including the axis O of the projection part **11***b*, the first melt portion **241** includes the second projection portions **243***a* and **243***b* projecting toward the electrode base material **11***a* side, and the penetration portion **244** provided therebetween, thereby increasing the surface area of the first melt portion **241** in the boundary between the first melt portion **241** and the electrode base material **11***a*.

Consequently, it is possible to increase the joining strength between the electrode base material **11***a* and the intermediate member **13** which are joined to each other via the first melt portion **241**.

The following summarizes features of the present embodiments.

A spark plug in one aspect of the present invention is provided with a center electrode and a ground electrode. In this spark plug, the ground electrode includes an electrode tip having a facing surface facing a distal end portion of the center electrode; an electrode base material supporting the electrode tip; an intermediate member disposed between the electrode tip and the electrode base material; and a melt portion containing a component of the electrode base material and a component of the intermediate member, and disposed at least at a part of a boundary between the electrode base material and the intermediate member. In addition, a part of the melt portion which is formed at a position radially inside the facing surface includes, when observing a cross section including an axis of the ground electrode, a boundary line between the intermediate member and the melt portion which has at least two first projection portions projecting toward an electrode tip side and a boundary line between the electrode base material and the melt portion which has at least two second projection portions projecting toward an opposite side of the first projection portions. According to the above configuration, in a cross section including the axis of the ground electrode, the boundary line between the intermediate member and the melt portion includes at least the two first projection portions projecting toward the electrode tip side, thereby increasing the surface area of the melt portion in the boundary between the melt portion and the intermediate member. In addition, in the cross section of the ground electrode, the boundary line between the electrode base material and the melt portion includes at least the two second projection portions projecting toward the opposite side of the first projection portions, thereby increasing the surface area of the melt portion in the boundary between the melt portion and the electrode base material. Consequently, it is possible to increase the joining strength between the electrode base material and the intermediate member which are joined to each other via the melt portion.

In the spark plug in another aspect of the present invention, the intermediate member includes a body portion positioned on an electrode tip side and a flange portion positioned on an electrode base material side and having a diameter larger than that of the body portion, and, in the cross section including the axis of the ground electrode, a height of at least one of the first projection portions is higher than that of the flange portion in an axial direction. According to the above configuration, a ground electrode having a structure in which the intermediate member hardly moves in the radial direction of the electrode tip can be obtained. Consequently, it is possible to further increase the joining strength between the electrode base material and the intermediate member which are joined to each other via the melt portion.

As the above, according to a spark plug in one aspect of the present invention, it is possible to increase the joining strength between a ground electrode base material and an intermediate member.

The entire contents of Japanese Patent Application 2020-138501 filed Aug. 19, 2020 is incorporated herein by reference.

Although the present invention has been described with reference to the present embodiments and its variations, the present embodiments and its variations are intended to facilitate understanding of the present invention and are not intended to limit the present invention thereto. Various changes and modifications may be made to the present embodiments and its variations without departing from the scope of the present invention. The present invention includes equivalents thereof. In addition, a configuration obtained in the combination of the configurations of the embodiments different from each other which have been explained in the present specification is also included in the scope of the present invention.

The invention claimed is:

1. A spark plug comprising:

a center electrode; and

a ground electrode,

wherein the ground electrode includes:

an electrode tip having a facing surface facing a distal end portion of the center electrode;

an electrode base material supporting the electrode tip;

an intermediate member disposed between the electrode tip and the electrode base material; and

a melt portion containing a component of the electrode base material and a component of the intermediate member, and disposed at least at a part of a boundary between the electrode base material and the intermediate member, and

wherein a part of the melt portion which is formed at a position radially inside the facing surface includes, when observing a cross section including an axis of the ground electrode, a boundary line between the inter-

mediate member and the melt portion which has at least two first projection portions projecting toward an electrode tip side and a boundary line between the electrode base material and the melt portion which has at least two second projection portions projecting toward an opposite side of the first projection portions.

2. The spark plug according to claim **1**, wherein the intermediate member includes a body portion positioned on an electrode tip side and a flange portion positioned on an electrode base material side, and having a diameter larger than that of the body portion, and

wherein, in the cross section including the axis of the ground electrode, a height of at least one of the first projection portions is higher than that of the flange portion in an axial direction.

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